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PILE-OF-PLATES POLARIZER FOR THE VACUUM ULTRAVIOLET

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27256 ABSTRACT

A pile-of-plates polarizer and analyzer for the spectral region 1200-1600A have been constructed from cleaved LiF plates 13 mm in diameter and 0.3 to 0.8 mm thick. Both polarizer and analyzer consist of identical cylinders with 3/16 inch apertures and contain eight 1 mm slots cut at an angle of 60° to the axis of the cylinder. The slots are arranged in two opposing groups of four each to give an on axis emergent beam. Measurements with a six plate polarizer gave polarizations of 82% and 65% at 1200 and 1600A respectively. The effective transmission of the polarizer was 4.3% and 21.5% at these two wavelengths. Performance characteristics of the polarizer will be presented and discussed.

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INTRODUCTION

The importance of measurements utilizing polarized radiation in giving fundamental information concerning electromagnetic interactions in a variety of fields has been well established. Due to the lack of suitable polarizers for radiation below 2000A and the multitude of significant work which can be done in more accessible regions of the spectrum, few attempts have been made to exploit polarization measurements in the far ultraviolet. Recent theoretical[1] and experimental[2] advances in solid state ultraviolet spectroscopy, which have re-emphasized the significance of polarization studies should soon drastically change this situation.

The present paper reports on a pile-of-plates polarizer for the region 2000-1200A which was constructed in order to carry out measurements to determine and identify interband transitions in non-cubic solids. In the absence of suitable dichroic materials below 2000A, Brewster angle reflection and transmission techniques appear most easily exploited for the production of polarized UV radiation. The polarizer to be described is a conventional transmission polarizer using LiF plates. The transmission technique was chosen over the more efficient reflection method in order to give a more adaptable geometry for future spectroscopic work. Once linearly polarized radiation has been produced it should not be too difficult to construct quarter wave plates from strained isotropic materials thus leading to the production of circularly polarized radiation. Indeed preliminary considerations using strained LiF indicates that such UV optical elements are feasible. The new areas, e.g., in optical pumping and others opened up by such an advance should be considerable.

DESCRIPTION AND RESULTS

The LiF pile-of-plates polarizer was constructed from thin plates cleaved from a cylindrical blank 13 mm in diameter. Plates varying in thickness from 0.3 to 0.8 mm were used. The polarizer and analyzer, which could be rotated while under vacuum, consisted of two stainless steel cylinders 3.00" long and 0.562" in diameter having a 3/16" axial hole. Each cylinder contained eight slots cut at 30^{o} to the axis, giving an angle of incidence of 60^{o}, and arranged in two opposing groups of four each to insure an on-axis emergent beam. As is well known[3], optimum performance is obtained with such polarizers when the angle of incidence just exceeds the Brewster angle. Since this angle for LiF at 1200A is $58^{o}40'$ while that at 2000A is $55^{o}41'$, an incident angle of 60^{o} represents a good compromise.

Measurements with the polarizer have been made (a) to determine its working characteristics, (b) to determine the polarization of the monochromator used and (c) to explore the polarization dependence of the far UV reflection peaks recently observed for crystals with the wurtzite structure[4]. The measurements concerning the operating characteristics of the polarizer will be discussed.

Figure 1 shows the polarization characteristics of the device for six and four plates. The theoretical values pertain to the two standard expressions giving the polarization for such polarizers depending on whether or not internally reflected beams are included in the transmitted beam[5]. Since the internally reflected beams consist entirely of radiation polarized perpendicular to the plane of incidence, lower values are predicted when they are included in the analysis. The fact that the measured polarization is close to that calculated using the simple expression indicates that internally reflected beams were virtually eliminated by the natural wedging and fanning of the plates. For comparison a percent polarization of 80% corresponds to a rejection ratio $I_o/I_{90} = 9/1$ while 50% polarization corresponds to $I_o/I_{90} = 3/1$.

The effective transmission of the polarizing plates is shown in Fig. 2. The data are plotted so that the maximum transmission expected is 50%, i.e., the transmission involved is the ratio of the transmitted polarized radiation to the incident unpolarized radiation. In order to insure that the effects observed were due to polarized radiation and not transmission effects arising from the rotation of the plates, the angular extinction dependence of the polarizer and analyzer was measured for several wavelengths. The results are shown in Fig. 3 and compared to the expected cosine squared dependence. The agreement with the cosine squared curve shows that a high degree of polarization was indeed produced.

Although the monochromator used for the measurements operated at normal incidence so that the exit beam should be unpolarized, the novelty of the UV polarizer suggested that a direct confirmation of this fact would be desirable. The results of this measurement showed that the maximum apparent polarization of the beam was in the range 1-2 percent. Since changes in transmission of the polarizer due to irregularities in the cleaved plates could easily amount to this much, it was concluded that the beam was completely unpolarized. It would be of considerable interest to repeat this measurement on Seya and grazing incidence instruments.

SUMMARY

A pile-of-plates polarizer for the 2000-1200A region has been constructed and shown to be adequate for a wide range of polarization studies beyond the limit of available polarizers. Optimization of the quality and position of plates, e.g., by using polished rather than cleaved surfaces should markedly increase the performance of the device. Measurements of reflection spectra of crystals having the wurtzite structure have been carried out[6] using the polarizer and indicate that at least in one field, i.e., UV solid state spectroscopy, significant new results can be obtained. It is anticipated that the use of these polarizers will lead to an extension of other visible optical techniques such as optical pumping and the study of optical absorption of ions located in anisotropic crystalline fields into the vacuum ultraviolet.

FIGURE CAPTIONS

Figure 1 - Spectral dependence of the polarization of LiF pile-of-plates polarizers. I_0 and I_{90} are the transmitted intensities with the plane of incidence of the analyzer parallel and perpendicular respectively to the plane of incidence of the polarizer[5].

Figure 2 - Spectral dependence of the effective transmission of LiF pile-of-plates polarizers. The ratio of the intensities of the polarized transmitted beam to the unpolarized incident beam is plotted.

Figure 3 - Angular extinction characteristics of a LiF pile-of-plates polarizer. The measured values for the wavelengths listed all fall within the flags shown on the plotted points.

REFERENCES

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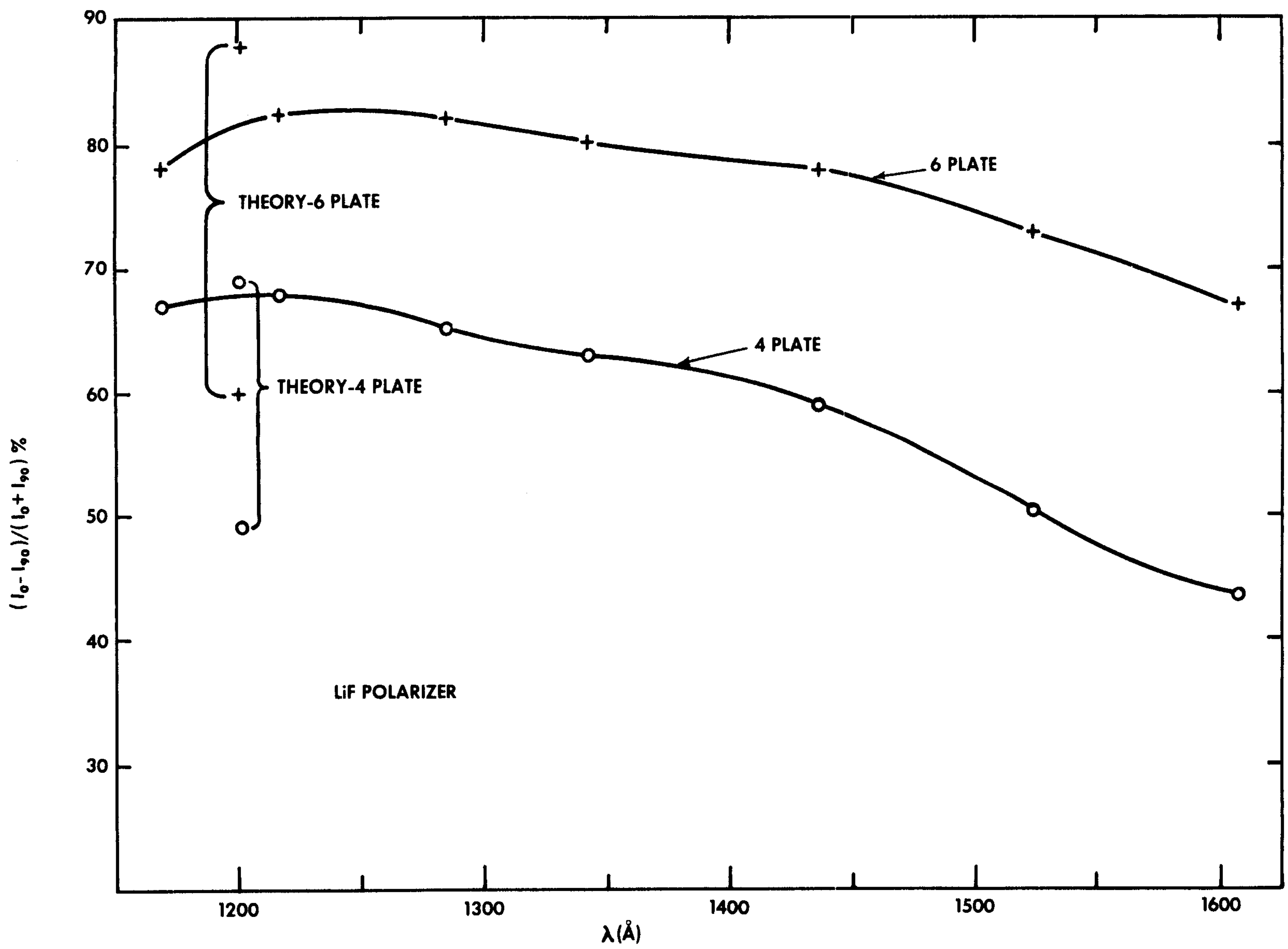
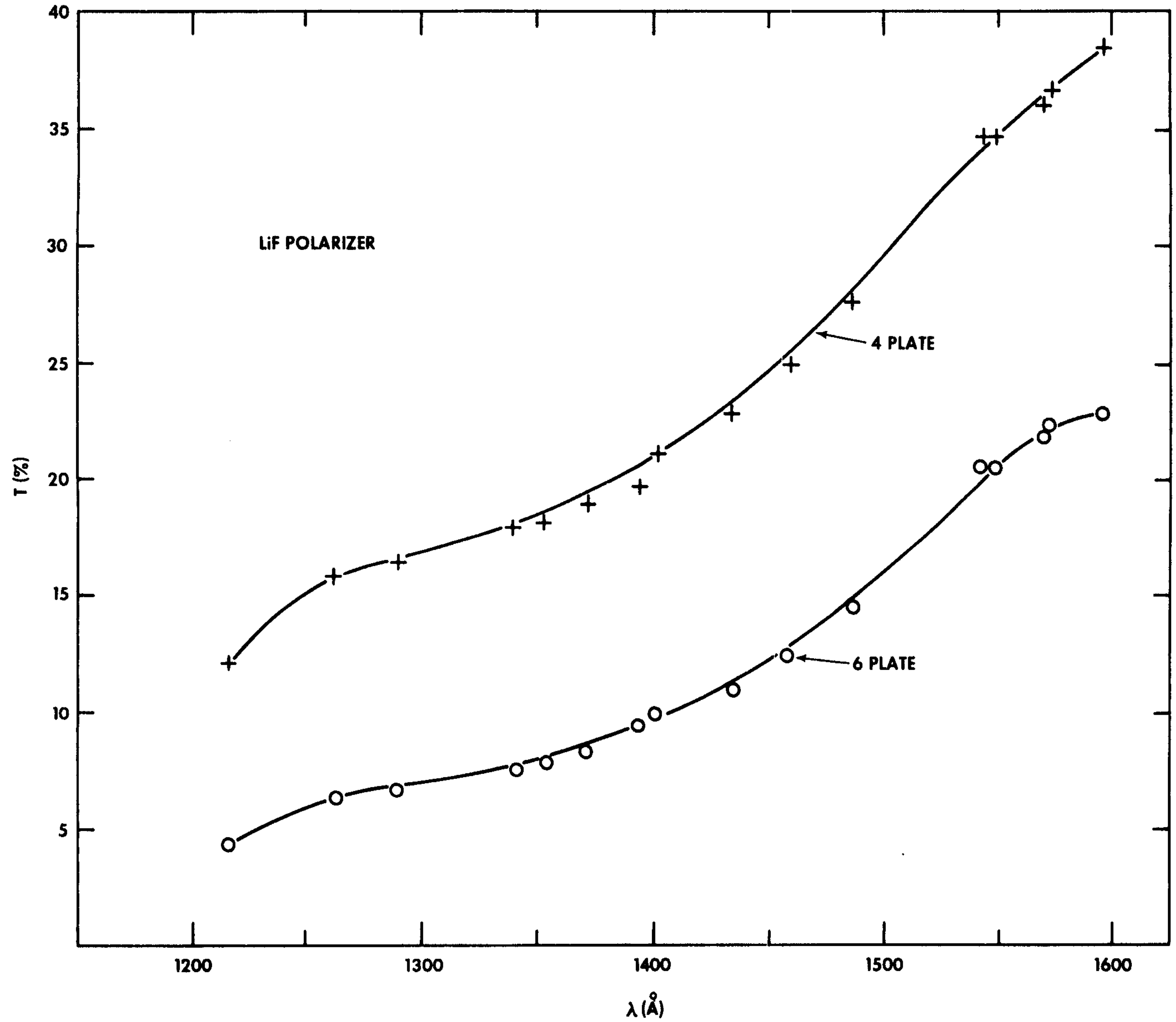
2. M. Cardona, Solid State Communications 1, 109 (1963).
3. G. R. Bird and W. A. Shurcliff, JOSA 49, 235 (1959).
4. W. C. Walker and J. Osantowski; J. Phys. Chem. Solids, to be published, 1964.
5. The theoretical values were calculated from the expressions

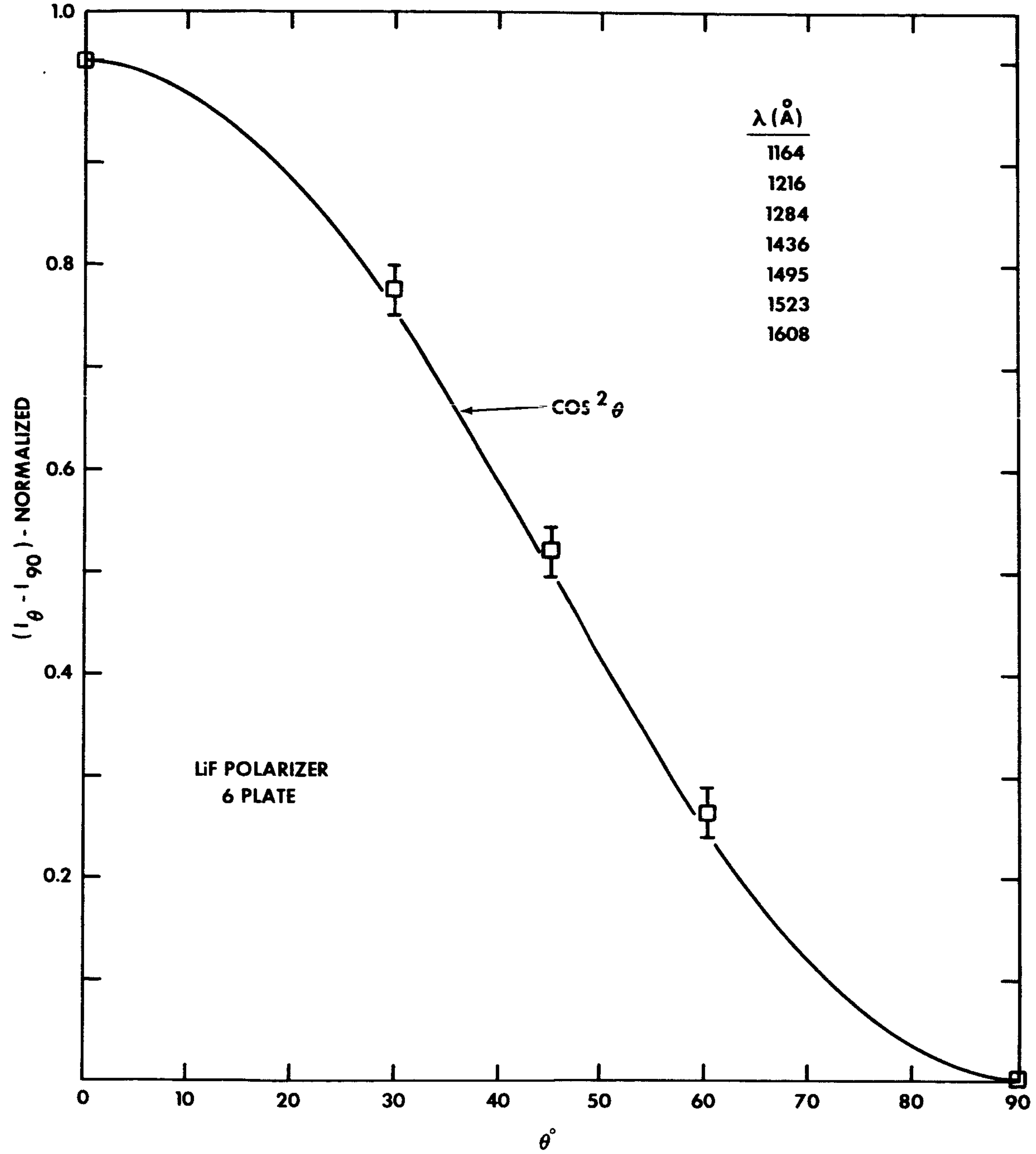
$$P = \frac{1 - \left(\frac{2n}{1+n^2}\right)^{4m}}{1+\left(\frac{2n}{1+n^2}\right)^{4m}}$$ when internally reflected beams are neglected and $$P = \frac{m}{m + \left(\frac{2m}{n^2-1}\right)^2}$$

   when they are included, where m is the number of plates and n is the index of refraction. See reference 3.
6. W. C. Walker and J. Osantowski, Bull. Amer. Phys. Society 9, 222 (1964).



90
80
70
60
50
40
30
THEORY-6 PLATE
6 PLATE
4 PLATE
THEORY-4 PLATE
LiF POLARIZER
1200
1300
1400
1500
1600
λ(Å)
$(I_0 - I_{90})/(I_0 + I_{90})$ %


LiF POLARIZER
4 PLATE
6 PLATE
T (%)
λ (Å)
40
35
30
25
20
15
10
5
1200
1300
1400
1500
1600



1.0
0.8
0.6
0.4
0.2
0
10
20
30
40
50
60
70
80
90
θ°
(I_θ - I_90) - NORMALIZED
λ (Å)
1164
1216
1284
1436
1495
1523
1608
COS ²θ
LiF POLARIZER
6 PLATE